THE SIDEREAL MESSENGER.

CONDUCTED BY WM. W. PAYNE,

DIRECTOR OF CARLETON COLLEGE OBSERVATORY.

MAY, 1888.

Thou Lord in the beginning hast laid the foundation of the earth and the heavens are the works of thy hands.

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THE RELATION OF SHORT-PERIOD COMETS TO THE ZONE OF ASTEROIDS.

BY DANIEL KIRKWOOD.

FOR THE MESSENGER.

The comets whose periods are inlcuded between those of Mars and Jupiter have a striking family likeness. The conjecture that the cluster had a common origin in the zone of asteroids seemed therefore not improbable, and was adopted by the writer, though with some hesitation, more than twenty years since.* The question, however, is still undecided; the most prominent theories of the cluster's origin being the following:

(1.) The theory of capture by Jupiter.—The well-known views of La Place in regard to the entrance of comets into the solar system may be found in Note VII., Vol. II., of his *Systeme du Monde*.† Similar views have been advocated by M. Faye, Professor H. A. Newton, and others.

(2.) The theory of explosion.—According to this hypothesis comets have been thrown out by an eruptive force from the major planets, as gaseous matter is often seen to be projected from the sun's surface. This view is sustained with much ability by Mr. R. A. Proctor.

(3.) The asteroidal theory, already referred to.—In this scheme, suggested by the late Stephen Alexander, LL. D.,‡ the short-period comets were originally asteroids so situated in the group that they were liable to great perturbation by Jupiter. The cluster, as hitherto observed, contains twenty-two members. For convenience of reference a conspectus of their elements is given below:

* Met. Astr. pp. 118, 119.
† They are also briefly stated in Met. Astr. pp. 117, 118.
‡ Gould's Astr. Jour. Nos. 19, 20.

Table of the Elements of the Asteroidal Comets.

No.	Designation.	Mean Distance	Eccen.	Per. Distance	App. Distance	Mean Daily Mot	Inclina-tion.
1	Encke	2.2150	0.8458	0.3423	4.0969	1077″.0	12°54′
2	Blainpan	2.8490	0.6867	0.8926	4.8060	737 .8	9 1
3	1766, II	2.9340	0.8640	0.3990	5.4670	706 .1	8 2
4	Tempel (1873)	3.0051	0.5525	1.3447	4.6656	681 .3	12 45
5	Barnard (1884)	3.0743	0.5840	1.2788	4.8700	657 .8	5 28
6	Clausen (1743)	3.0913	0.7213	0.8615	5.3211	652 .8	1 54
7	Brorsen	3.1015	0.8098	0.5899	5.6129	649 .6	29 23
8	De Vico	3.1028	0.6173	1.1863	5.0194	648 .8	2 55
9	Tempel-Swift	3.1180	0.6560	1.0726	5.1627	644 .6	5 24
10	Lexell	3.1560	0.7861	0.6745	5.6375	632 .8	1 34
11	Pigott	3.1583	0.6784	1.4953	5.3009	621 .1	44 53
12	Winnecke	3.2326	0.7268	0.8832	5.5820	610 .5	14 27
13	Brooks	3.4102	0.7840	0.7366	6.0838	563 .1	12 56
14	Tempel	3.4844	0.4051	2.0733	4.8973	545 .4	10 50
{15	Biela	3.5139	0.7552	0.8602	6.1673	538 .7	12 56
{15′	Biela′	3.5289	0.7551	0.8606	6.1969	535 .2	12 34
16	Tuttle	3.5222	0.6737	1.1493	5.8951	536 .9	19 30
17	Finlay	3.5435	0.7181	0.9989	6.0881	532 .7	3 2
18	D'Arrest	3.5491	0.6263	1.3264	5.7720	530 .8	15 42
19	{Wolf, 1884	3.5716	0.5599	1.5719	5.5717	525 .5	25 15
19′	{Before 1875	4.6100	0.2787	3.3252	5.8948	358 .1	27 37
20	Coggia	3.6241	0.7876	0.7698	6.4784	512 .7	26 44
21	Fay	3.8540	0.5490	1.7381	5.9701	469 .0	11 20
22	Denning	4.2732	0.8303	0.7252	7.8212	400 .6	6 50

Table of the Elements of the Asteroidal Comets.

No.	Period.	Long. of Per.	Long. of Asc. N.	Time of Per. Passage.	Calculator.	Date of Disc.
1	3.307y	158°33′	334°37′	1885, Mar. 7	Backlund.	1786, Jan. 30
2	4.809	67 19	77 14	1819, Nov. 20	Encke.	1819, Nov. 28
3	5.025	251 13	74 11	1766, Apr. 26	Burckhardt.	1766, Apr. 1
4	5.209	306 7	121 2	1884, Nov. 20	Schulhof.	1873, July 28
5	5.394	306 11	5 37	1884, Aug. 16	Egbert.	1884, July 16
6	5.435	93 20	86 54	1743, Jan. 8	Clausen.	1743, Feb. 10
7	5.462	116 15	101 19	1879, Mar. 30	Schulze.	1846, Feb. 26
8	5.469	342 31	63 50	1844, Sept. 2	Brunnow.	1844, Aug. 22
9	5.505	43 10	297 1	1886, May 9	Bossert.	1869, Nov. 27
10	5.607	356 17	131 59	1770, Aug. 13	Leverrier.	1770, June 14
11	5.613	49 32	55 12	1783, Nov. 19	Burckhardt.	1783, Nov. 19
12	5.812	276 4	101 56	1886, Sept. 4	A. Palisa.	1858, Jan. 4
13	6.300	229 46	53 3	1886, June 6	Hind.	1886, May 22
14	6.507	241 22	72 24	1885, Sept. 25	Gautier.	1873, July 3
{15	6.587	109 5	245 50	1852, Sept. 23	D'Arrest.	1826, Feb. 28
{15′	6.629	108 58	245 58	1852, Sept. 23	D'Arrest.	1826, Feb. 28
16	6.610	200 47	175 4	1858, May 4	Schulhof.	1858, May 2
17	6.670	7 34	52 30	1886, Nov. 22	Krueger.	1886, Sep. 26
18	6.686	319 11	146 7	1884, Jan. 13	Villarceau and Leveau.	1851, June 27
{19	6.749	19 3	206 22	1884, Nov. 17	Lehmann-Filhes.	1884, Sep. 17
{19′	9.898	352 37	207 34	1868, Sept. 24	Lehmann-Filhes.	1884, Sep 17
20	6.900	85 42	248 47	1873, Dec. 3	Schulhof.	1873, Nov. 10
21	7.566	50 49	209 35	1881, Jan. 22	Moller.	1843, Nov 27
22	8.833	18 36	65 52	1881, Sept. 28	Plummer.	1881, Oct. 3

REMARKS ON THE TABLE.

(1.) If the acceleration of Encke's comet has been uniform its period was two-sevenths of Jupiter's about A. D. 600.

(2.) The period of No. 4 is four-ninths that of Jupiter; of No. 12 (Winnecke's), six-elevenths; the periods of Nos. 15

and 16 are five-ninths that of Jupiter, and those of Faye and Denning, approximately two-thirds.

(3.) Several members of the group, viz., Nos. 2, 3, 6, 8, 10, 11 and 15, have mysteriously disappeared. For this fact we may assign either of two causes; dissolution into parts below the limits of visibility, or the transformation of orbits by Jupiter's influence. Biela's comet is an example of the former; Lexell's, of the latter. These being known and sufficient causes, no others need be sought for.

(4.) The perihelia are thus distributed:

In the 180° from 110° to 290°.................. 7, or 33 per cent.
In the 180° from 290° to 110°..................15, or 67 per cent.

This maximum coincides with that of the minor planets. See "The Asteroids," p. 50.

DID THE SHORT-PERIOD COMETS ORIGINATE WITHIN JUPITER'S ORBIT?

In the *Monthly Notices of the Royal Astronomical Society* for November, 1872, and in his subsequent writings, Mr. Proctor has presented arguments of no ordinary weight against the theory of capture. His reasoning need not here be repeated. It may be remarked, however, that the explosion hypothesis is not the only alternative. His mathematical objections do not hold against the theory of an asteroidal origin. Let us, therefore, briefly consider a few of the facts which may be advanced in its favor:

(1.) *All* the members of the cluster have direct motion. It may be admited that on the theory of capture a majority of the motions would be direct. Jupiter's influence, however, could not in all cases reverse the direction of the cometary mass in its approach to the sun; and of the twenty-two discovered, some might be expected to have a retrograde motion.

(2.) No example of the transformation of a parabolic to an elliptic orbit by Jupiter's influence is recorded as a historical fact.

(3.) The asteroid zone is an abundant source of supply, and the dominating influence of Jupiter a true and sufficient cause for the change of orbits. The history of Lexell's comet is a striking illustration. Before its close approach to Jupiter in 1767, it had been moving in an ellipse whose perihe-

lion was so remote that the comet could never be seen from the earth, though, as in the case of other members of the group, its period was included between those of Mars and Jupiter. At that epoch Jupiter's influence threw it into a new orbit, corresponding to a period of five and one-half years. After one revolution of the planet and two of the comet another close approach so modified the elliptic elements that the body has not since been seen. Its future identification, however, as a short-period comet, may not yet be impossible.*

(4.) The comet which passed its perihelion on the 17th of November, 1884, affords another instance of remarkable disturbance. Before 1875 its orbit was an ellipse whose eccentricity was only 0.2787—a less deviation from the circular form than those of twelve known asteroids. Its perihelion distance was 3.325—beyond the limit of visibility by ordinary telescopes. Its aphelion was a short distance beyond Jupiter's orbit; hence its liability to great perturbation. So close was its approach to that planet in May, 1875, that its orbit was transformed into that designated as No. 19 of the foregoing table. Had this body been detected before the transformation of its orbit it would doubtless have been considered an asteroid—more distant indeed than any now known, but in no other respect very clearly distinguished. Its eccentricity was doubled in the perturbation.†

OBJECTIONS.

(1.) It may be objected that this theory is not general and that in the case of other comets we must have recourse either to the theory of La Place or that of Proctor. If, in the cosmogony of La Place, nebulous bodies, "strangers to our system," entered from inter-*stellar* space, may not others, consistently with the same view, have had an inter-*planetary* origin?

(2.) The "asteroidal comets" differ from asteroids in their physical characteristics. The latter are said to change their aspect solely or chiefly with their change of distance from the earth. The former vary greatly in apparent magnitude with their changing distance from the sun, some even devel-

* See Leverrier's discussion in *Mem. Acad. Sci.*, 1847.

† Annuaire, 1886, pp. 249, 250.

oping tails in approaching perihelion. Can these facts be harmonized with the theory that such bodies are but stray asteroids?

This objection is plausible but perhaps not fatal. In the case of some asteroids a variation of apparent magnitude, greater than that due to varying distance from the earth, has undoubtedly been noticed.* It may also be stated that the observed physical changes in the short-period comets occur mostly, if not entirely, when they are in the vicinity of perihelion, or within the zone of asteroids. The phenomena might disappear with decreasing eccentricity.

ASTRONOMICAL PHOTOGRAPHY.† ‡

A star of any given order of lustre emits just two and a half times as much light as a star of the magnitude next below. One of the sixteenth is accordingly a million times fainter than one of the first magnitude, and under identical conditions takes a million times longer to get photographed. This is the proper and only definite criterion of the rank of such feebly luminous objects, visual estimates of which are little better than guess-work.

It is true that color exercises a disturbing influence owing to the predominant sensitiveness of silver salts to the more refrangible rays. Aldebaran, for instance, is reduced by the fiery tinge of its light to the fifth or sixth *chemical* rank; and small red stars are frequently missing from photographs which display crowds of objects equally or less bright to the eye. Such discrepancies, however, have an interest of their own, and they do not impair the general correspondence

* The Asteroids, p. 53. † Continued from p. 153.

‡ From January *Edinburgh Review*, being a review of the following articles:

1. La Photographie Astronomique a l'Observatoire de Paris et la Carte du Ciel. Par M. le Contre-Amiral E. Mouchez. Paris: 1887.

2. An Investigation in Stellar Photography conducted at the Harvard College Observatory. By Edward C. Pickering. Cambridge, U. S.: 1886.

3. First Annual Report of the Photographic Study of Stellar Spectra conducted at the Harvard College Observatory. By Edward C. Pickering, Director. Cambridge, U. S.: 1887.

4. The Applications of Photography in Astronomy. Lecture delivered at the Royal Insitution, Friday, June 3, 1887. By David Gill, LL. D., F. R. S. (The Observatory, July and August, 1887.)

5. Die Photographie im Dienste der Astronomie. Von O. Struve. (Bulletine de l'Academie Imperiale des Sciences de St. Petersbourg. Tome xxx. No. 4: 1886.)

between visual and photographic evaluations of brightness. Nor, even when they differ, is there any valid reason for preferring the former to the latter. Both serve as means to the same ends; and chemical determinations are in so far at least to be preferred that they are authentic over a wider range.

Accurate comparisons of stellar brilliance serve two chief purposes—an individual, so to speak, and a general. Taken separately, they are a direct test of variability; taken together, and on an average, they are a safe guide to distribution.

The great problem of the constitution of the sidereal universe is not to be solved by a stroke of genius. The generations of men are but as hours for its study; each contributes its little quota of gathered facts, and more or less ineffectual thoughts, and goes to its rest only a shade less ignorant than its predecessors. It was Herschel's great merit to have perceived that no reasoning on the subject could stand unless based on a solid substructure of statistics, and he even made the attempt by his "guages," or counts of stars in various directions, to supply the needful data. But the information attainable by the labors of an individual was as nothing compared with what must be collected before profitable discussions could even begin. Now at last the requisite materials are, it would seem, about to be provided, and a long pause in the progress of knowledge may be compensated by a leap forward. When the photographic survey of the heavens is completed, conclusions of reasonable certainty on some fundamental points connected with the galactic structure will be within comparatively easy reach.

The mere counting of the stars of various orders on the plates will show whether they give any signs of *thinning out*. Stars of any assigned brightness should, on the supposition of tolerably even scattering, be nearly four times as numerous as those one magnitude brighter. There should be more of them because they occupy a wider shell of space. Thus, a marked scarcity, local or general, of faint stars would afford evidence of an approach to the limits of the system; it would indicate a determinate boundary to the Milky Way.

It is practically certain that such a boundary must somewhere exist. Were the stars agglomerated in the Galaxy

infinite in number they would emit an infinite quantity of light; and (unless on the gratuitous assumption of its extinction in space) our skies should blaze with a uniform and unendurable lustre. But the sum-total of stellar radiations striking the earth is very small. It has been estimated at one-tenth of full moonlight; it is in reality probably much less. The grand aggregate number of stars, however, corresponding to that amount of light comes out, by a recent computation, at no less than *sixty-six milliards*, and the frontier line of the system constituted by them is drawn at the average distance of stars of the seventeenth magnitude.* All this is, of course, largely hypothetical, but it is a certain and a curious fact that we receive much more light from stars invisible than from those visible to the naked eye. All the lucid orbs might, in fact, be withdrawn without sensibly diminishing the general illumination of the sky.†

The concentration of stars towards the Milky Way appears, from the evidence of Schönfeld's zones, to be far less marked in the southern than in the northern hemisphere.‡ Photographic statistics will supply the means of deciding whether any such difference really exists. They will, moreover, test the truth of M. Celoria's interesting theory of a double Galaxy. The sidereal world is, in his view, composed of two rings of stars at widely different distances from us, one inclined at a considerable angle to and including the other, the sun being situated in the plane of neither, and excentrically towards both. We shall see whether the twenty millions about to be charted conform to this plan.

The movements of the stars, as tending to reveal the laws governing the stellar commonwealth, are of even higher interest than their distribution; but we are still very much in the dark about them. The impending photographic survey will be a preparatory measure for the acquiring extended knowledge on the subject. About the year 2000 A. D. the seed planted in our time will have begun to bear fruit. A fresh determination of their places for that epoch will reveal the amount and direction of their changes in the interim. Something of the meaning of those changes can hardly fail to become legible. Stars associated by a general "drift" can

* Hermite, "L'Astronomie," tome v. p. 412. † Ibid. p. 409.
‡ Seeliger, "Sitzungsberichte," Heft ii. p. 228. Munich: 1886.

be marshalled into systems; others in specially rapid motion —the so-called "flying" or "runaway" stars—will show their common peculiarities; an inkling of the purpose of the sun's mysterious journey through space may be gained, and its rate and aim, in any case, ascertained; his companions on the voyage may even be picked out. The motion-harmonies of the Cosmos will begin to sound intelligibly in the ears of humanity.

But present as well as prospective results may be looked for from the contemplated star-enrollment. Its progress must inevitably be attended by interesting disclosures. Now a new asteroid will stamp its light track on a plate, or a remote giant planet will be distinguished by disappearance from or intrusion into a duplicate record; a comet approaching the sun will announce itself from afar; stars will show unsuspected nebulous appendages; others, too faint for visual separation, will spontaneously divide on the chemical retina.

Our readers can now to some extent appreciate the importance of securing a trustworthy picture of the sky for a given epoch. But this was not the sole care of the astronomers assembled at Paris. The miscellaneous application of photography also engaged their attention; and by appointing M. Janssen and Mr. Common as a permanent committee for the purpose of studying and promoting them, they made sure, in this direction also, of rapid progress.

Mr. Common's well-known photograph of the great nebula in Orion, taken in Ealing, January 30, 1883, not only superseded all previously existing delineations of that strange object, but virtually prohibited any such being attempted in future. Changes in its condition, it was made plain, must thenceforward be investigated by a comparison of photographs taken at various dates. No living astronomer has devoted more care to the telescopic study than Professor E. S. Holden, now director of the Lick Observatory. Yet he frankly admits that "every important result reached" by an assiduous scrutiny of four years with the Washington twenty-six-inch equatorial, "and very many not comprised in it, were attained by Mr. Common's photograph, which required an exposure of forty minutes only."*

* Photography the Servant of Astronomy, p. 10.

Since about seven thousand nebulæ are now known, the field of research thus entered upon is sufficiently wide. And its cultivation must be largely disinterested. Time, for the most part, will be needed to ripen its results. Some centuries hence, for example, the examination of a "vitrified" picture of a spiral nebula dating, say, from 1890, may reveal alterations of form decisive on some leading points connected with the genesis of worlds.* Posterity will not, however, alone reap the benefits of such labors. Some first fruits have been already gathered. A photograph by Mr. Common of the central portion of the Andromeda showed that the star which blazed out near the nucleus in August, 1885, had no visible existence a year earlier. It was *not*, then, developed by some sudden catastrophe out of one of the minute stellar points powdering the surface of the nebula, but was "new" in the relative sense in which alone we can safely use the term.

The discovery of the nebulous condition of the Pleiades, again, has been an almost startling illustration of what may be learnt by sheer perseverance in exposing sensitive plates to the sky. Nearly thirty years ago M. Tempel, an exceptionally acute observer, detected a filmy veil thrown round, and floating far back from the bright star Merope; and Mr. Common *saw*, with his three-foot reflector, February 8, 1880, some additional misty patches in the same neighborhood. In general, however, the keen lustre of the grouped stars appeared relieved against perfectly dark space. Great then was the surprise of the MM. Henry on perceiving a little spiral nebula clinging round the star Maia, on a plate exposed during three hours, November 16, 1885. The light of this remarkable object possesses far more chemical than visual intensity. Were its analysis possible, it would hence doubtless prove to contain an unusually large proportion of ultra-violet rays. It is of such evanescent faintness that its direct detection was highly improbable; but since it has been known to exist, careful looking has brought it into view with several large telescopes. It was first visually observed on February 5, 1886, with the new Pulkowa refractor of thirty inches aperture, and M. Kammermann, by using a fluorescent eyepiece, contrived to get a sight of it with the ten-inch of the Geneva Observatory.

* Mouchez, op. cit. p. 61.

The further prosecution of the inquiry is due to Mr. Roberts of Liverpool. With his twenty-inch reflector he obtained, on October 24, 1886, a picture of the Pleiades that can only be described as astounding. The whole group is shown by it as involved in one vast nebulous formation.* "Streamers and fleecy masses" extend from star to star. Nebulæ in wings and trains, nebulæ in patches, whisps and streaks, seem to fill the system, as clouds choke a mountain valley and blend together the over exposed blotches which represent the action of stellar rays. What processes of nature may be indicated by these unexpected appearances we do not know; but the upshot of recent investigation† leads us to suppose them connected with the presence of copious meteoric supplies, and their infalls upon the associated stars.

The mechanical condition of globular clusters of stars offers a problem of extraordinary interest and complexity. It can, however, be usefully studied only by the aid of photography. Take as an example the marvellous agglomeration in the constellation Hercules. The many thousands of stars composing it run together towards the centre, into one unbroken blaze utterly defying measurement of every kind; while the outlying "grains of bright dust" bewilder the eye so as to incapacitate it for methodical operations.‡ But from the the Paris plate all such separate stars can and will be perfectly well mapped and catalogued. Dr. O. Lohse has since 1884 been working in Potsdam with signal success in the same department; and thus data are being stored up for the future detection of interstitial movements in these complex systems. They must, in general, be extremely minute; and a star in the cluster No. 1440, shown as markedly displaced in eighteen years by a comparison of M. Von Gothard's photographs with Vogel's micrometric measures,§ will most likely prove to be accidentally projected *upon* the cluster, and not to form part of it.

Doubts as to the superiority of the photographic method of measurement for double stars can only arise where the components are considerably unequal. In this case the

* Monthly Notices, vol. xlvii. p. 24.
† Described by Mr. Norman Lockyer, before the Royal Society, Nov. 17, 1887.
‡ Mouchez, op. cit. p. 54. § Astr. Nachrichten, No. 2777.

brighter star, necessarily over-exposed, gives an indistinct and distended image ill suited for precise determinations. The same difficulty impedes photographic operations for ascertaining the parallaxes of large stars. Professor Pritchard has, however, shown conclusively by his successful measures of 61 Cygni that this most exacting problem of stellar astronomy lies for the most part well within the competence of the camera. Its prerogatives in the matter are obvious, and the result of its employment will infallibly be a rapid multiplication of the stars at known distances from our system.

We are far from having reckoned up all the tasks of astronomical photography. They become every year more numerous; their scope widens as we contemplate it, while that of eye observations dwindles proportionately. Even transits, it appears, can now be taken with increased accuracy on the sensitive plate. It is indeed difficult to set bounds to the revolution in progress by which all the practical methods of celestial science are being swiftly and irresistibly transformed.

The tendency of the camera to usurp the functions of the eye is nowhere more apparent than in the study of stellar spectra. When Dr. Huggins laid before the Royal Society, December 6, 1876, a little print of the spectrum of Vega,* only a prophetic imagination could have anticipated that, within ten short years, so vast a development would be given to the subject. After the lapse of three years, the same eminent investigator communicated his discovery of the complete ultra-violet spectrum of hydrogen as depicted, dark by absorption, in the analyzed light of Vega and other white stars. This rhythmical series of vibrations, repeated, in varied terms, in the spectra of some metals,† may yet serve as a clue out of the labyrinth of speculation regarding the molecular constitution of matter. None of its nine invisible members occur in ordinary sunlight; but they appeared in a photograph of the spectrum of a prominence taken by Dr. Schuster during the total eclipse of 1882. Their presence would seem to be conditional upon a high

* The first photograph of a star spectrum showing lines was obtained by Dr. Draper, in 1872.

† Cornu, "Journal de Physique," Mars, 1886.

state of excitement by heat of the hydrogen atoms emitting them; and their strong reversal in the spectra of Sirius, Vega, and their congeners almost compels the belief that the photospheres of such stars are more intensely incandescent than that of our sun.

The work to which Dr. Henry Draper devoted his chief energies during the later years of his life was that of stellar spectroscopic photography; and it is now being prosecuted at Harvard College as a memorial to him, and with funds and instruments provided by his widow. "The attempt will be made to include all portions of the subject, so that the final results shall form a complete discussion of the constitution and condition of the stars as revealed by the spectra, so far as present scientific methods permit."* There can be little doubt that, under Professor Pickering's direction, this "attempt" will be successful. Already superb specimens of photographed spectra have been distributed, obtained by methods so expeditious as to enable stars by the score together to stamp the characters of their analyzed light on the same plate. And in sidereal astronomy, the subject matter of which is all but infinite, the quantity of information collected in a given time is nearly as important as its quality. Hence large expectations from the Harvard researches are justly entertained.

The spectroscope supplies information not only about the physical constitution, but about the movements of the stars, and it is safe to say that its messages on this head will henceforth be read almost exclusively by photographic means. The acquisition of power to determine, by the displacement of known lines in its spectrum, whether a heavenly body is moving towards or from the eye, and at what rate, is one of the most considerable of recent additions to the resources of astronomy. Its use as regards the stars, however, has hitherto been hampered by grave difficulties of observation. Small deviations of delicate lines kept continually thrilling and shivering by air tremors can be but insecurely registered. But on such photographs as Professor Pickering's (once provided with a standard of wave-length) the readings will be sure and easy.

* Draper Memorial, First Report, p. 3.

Here we find the natural meeting-place of the old and the new astronomies. Spectroscopy and photography here directly lend themselves to dynamical inquiries, and so help to found the future science of sidereal mechanics. They combine to measure movements otherwise wholly imperceptible. More complete data as to the mutual relations of the stars are thus afforded, and means provided for determining the rate of translation of the solar system by contrasting stellar rates of approach or recession in opposite quarters of the sky. Stars sensibly exempt from visual displacement because the whole of their motion is 'end on' can be discriminated from stars really almost immovable relative to the sun, because associated with it in a journey towards the same bourne in space. The members of the stellar group to which the sun belongs can in this way be identified, and some insight gained into its structure. And all this in the immediate future. For spectroscopic determinations of movement are complete in themselves. They evade the necessity for exact comparisons after the lapse of tedious years or centuries. They tell us at once *what is*.

Astronomical photography includes tasks of all kinds and suited to every capacity. The Baconian principle of the division of scientific labor will by it be brought into full play. One division of workers will devote themselves to the exposure and development of plates, another to their measurement. It may even happen that the first set of operations will be conducted in a different part of the globe from the second, as the Cape photographs are now in course of measurement at Groningen, and the Cordoba photographs at Boston. The same negatives may be studied by one astronomer in search of new members of the solar system; by another, for the purpose of detecting displacements due to annual parallax or proper motion; by a third, with a view to eliciting facts relative to stellar distribution; by a fourth, for the sake of information latent in them as to stellar variability. In each branch of sidereal astronomy photographic experts will arise skilled in developing the special conditions favorable to success in a special direction. The picturing of nebulæ is a totally different art from stellar chartography; double stars require modes of treatment not applicable to clusters; impressions for photometric purposes would be

wholly useless for measuring displacements; the obstacles met in depicting stellar spectra are of another order than those which impede the photographic sounding of space.

Several magnificent instruments will shortly be available for photographic use. A "bent equatorial," twenty-nine and a half inches in aperture, in preparation at Paris, will offer particular advantage for lunar and planetary work from the extremely long focus (fifty-nine feet) which its peculiar form enables it to receive. The Lick object-glass will collect nine times as much light as any actually existing photographic telescope.

"A single exposure," Professor Holden remarks,* "will give us a map of the sky comprising four square degrees on a plate twenty-four by twenty-four inches. A few minutes will impress on this plate a permanent record of the position and brightness of all the stars visible in even the largest telescopes. A comparison of two such plates, taken on different nights, will point out any changes which might easily escape the most minute observations by other methods. The sun's image unmagnified will be six inches in diameter; a large sunspot will be the size of one's finger-nail. Beautiful photographs of the planets can be taken so as to register with perfect accuracy the features of their surfaces. Comets and nebulæ can be studied at leisure from their automatic registers, as one studies a copperplate engraving. The variations of refraction from the horizon to the zenith can be made to record themselves for measurement. There is absolutely no end to the problems lying close at hand, and their number and their importance will develop with time. We are merely at the threshold of this subject."

But even the Lick refractor will be beaten out of the field, as regards luminous capacity, by the five-foot, silver-on-glass reflector which Mr. Common is now personally engaged in constructing. Twice as many rays as the other transmits will be concentrated by it, and its other qualities, unless they belie expectation, will correspond to its power. Unfortunately, however, there is another large factor in the account. A bad climate cripples the use of the most perfect instrument. Its size renders it only the more sensitive to atmospheric troubles. And Ealing is half submerged by the fogs of London, while Mount Hamilton, as an observing site, has no known rival in the world.

We have said enough to show that a new and hopeful era is opening for astronomy. It is greeted on all sides with the enthusiasm which the drawing of large possibilities never fails to evoke. The time-honored problem of "how the

* Photography the Servant of Astronomy, p. 10.

heavens move" presents itself under a novel aspect. Novel implements of research are being zealously adapted to its requirements. The shrinkage of films, the vitrification of negatives, the distension of photographic star-discs, devices for modifying the qualities of salts of silver, are being studied with the same patient ardour that Bessel brought to determinations of "collimation-errors" or "personal equation." There is no longer a "new" and an "old" astronomy. The two are fused into one, to the enormous advantage of both. It seems hardly possible to be over-sanguine as to the results.

ON THE NEBULAR HYPOTHESIS OF LA PLACE.*

BY GEORGE W. COAKLEY.†

The next question discussed by La Place is: How far may the atmosphere of such a rotating mass extend, especially above its equator, where the centrifugal force is greatest, and is most directly opposed to gravity? It is certain that the earth's atmosphere can not extend indefinitely above its equator; for the farther you go from the centre of the earth the less the force of gravity becomes in proportion to the square of the distance; while the higher up the atmosphere reaches, the greater the centrifugal force becomes over the equator, precisely in proportion to the distance from the axis, or, in this case, from the centre. So that we must ultimately reach a distance above the equator, at which gravity is so reduced, and centrifugal force so increased by the distance, that these two opposing forces are equal and neutralize each other. At the next step beyond the centrifugal force exceeds gravity, and the part of the atmosphere above the equator at this greater distance would cease to belong to the Earth, and would be driven away from it. But on the top of the atmosphere, at several degrees away from the equator on either side, the centrifugal force is less than just over the equator, and besides does not directly oppose gravity, so that those portions could still press down toward the Earth's surface. La Place calls the distance at

* Continued from page 137.

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which the centrifugal force just balances gravity, the *Centrifugal Limit.* Where would this centrifugal limit be over the Earth's equator, with our present rotation, once in about twenty-four hours? It is easily computed, and I find it to be, over the Earth's equator, at about nearly 27,000 miles from the centre, or about 23,000 miles above the surface of the Earth. It is well known that at the equator, and on the surface of the Earth, the centrifugal force is now about the $\frac{1}{289}$ of the force of gravity; and that if the Earth's angular velocity were about seventeen times as great as it is, or its time of rotation were reduced to about one hour and twenty-five minutes, objects at the equator would cease to have weight, or begin to be repelled from the Earth. Certainly, the whole of the atmosphere at the equator would then leave the Earth.

To come back to La Place's equation, and his discussion of it. He supposes now that the atmosphere of his rotating body has reached the *centrifugal limit* over the equator, and enquires what, in that case, is the ratio of the equatorial to the polar radius, or the ratio of R' to R. As he puts n for the angular velocity of his rotating body, at the unit's distance from the axis, and takes the equatorial radius of the nucleus for the unit of distance, hence n^2 is the centritugal force at the unit's distance, and $n^2 R'$ is the certrifugal force at the surface of the atmosphere over the equator. Again, $\frac{M}{1^2} = M$ is the force of gravity at the unit's distance from the centre, and $\frac{M}{R'^2}$ = the force of gravity at the surface of the atmosphere over the equator. Hence, at the *centrifugal limit*, we have $n^2 R' = \frac{M}{R'^2} \therefore \frac{n^2}{M} R'^3 = 1$. Hence his preceding equation, $\frac{n^2}{M} R'^3 = 2 \frac{R'-R}{R}$ becomes

$$1 = 2\left(\frac{R'}{R} - 1\right) = 2\frac{R'}{R} - 2 \therefore 2\frac{R'}{R} = 3, \therefore \frac{R'}{R} = \frac{3}{2}$$

It follows, therefore, that, at the *centrifugal limit* of the atmosphere of a rotating body, over the equator, the *equatorial radius* is to the *polar* precisely as 3 to 2. Moreover, we have found that when the *centrifugal limit* is reached we must have $\frac{n^2}{M} . R'^3 = 1$. Hence $n^2 R'^2 = \frac{M}{R'}$, or $n R' = \sqrt{\frac{M}{R'}}$. This

is the velocity of rotation at the surface of the atmosphere over the equator. If, therefore, M remains the same mass, or very nearly the same, we have the fact that the *equatorial velocity* at the surface of the atmosphere, when the *centrifugal limit* is reached, is either exactly, or very nearly proportional *inversely to the* SQUARE ROOT *of the radius of the limit*. This is precisely what is given also by Kepler's Third Law. Hence the assertion made by some writers that the velocity at this distance must be inversely as the *square of the distance* is entirely disproved by La Place's equations.

La Place next proves that when the atmosphere of a rotating body reaches the *centrifugal limit* over its equator, the equatorial radius, R' is then the greatest possible, and that there can be no greater ratio of the equatorial to the polar radius of the atmosphere of such a body than that of 3 to 2. From this fact he concludes that the very flattened form of the zodiacal light proves that it is not the atmosphere of the sun, but that it must revolve around him as a detached ring, somewhat perhaps like the rings of Saturn. The foregoing principles, strictly demonstrated, are the real foundation of La Place's celebrated nebular hypothesis.

Let us see now something of the use which he makes of these principles, and his mode of reasoning upon them. It should be remembered that, while the principles themselves are mathematically demonstrated in the *Mecanique Celeste*, they are afterwards merely stated without further proof in the *Exposition du Systeme du Monde*; and in the last note to the latter work La Place proposes his hypothesis.

The important parts of that note I shall present in a free but fair translation.

In order to arrive at the cause of the original motions of the planetary system, we have, says La Place, the five following phenomena:

(1) The motions of the planets in the same direction, and nearly in the same plane;

(2) The motions of the satellites in the same direction as those of the planets;

(3) The rotations of these different bodies, and of the Sun in the same directions as their orbital revolutions, and in planes that differ but little from each other;

(4) The nearly circular orbits, orbits of small eccentricity, both of the planets and of the satellites;

(5) On the contrary, the great eccentricity of the orbits of comets, their mutual inclinations at the same time having every possible value, and their directions as if abandoned to chance.

That La Place knew nothing of any nebular speculations of Kant is evident from his statement that Buffon is the only one that he knew who, since the discovery of the true system of the world, has endeavored to trace the origin of the planets and satellites. He then states Buffon's theory, and easily refutes it.

In proposing his own theory, La Place says:

Of whatever nature was the cause of the five phenomena before stated, since it has produced, or directed, the motions of the planets, it must have embraced all these bodies; and on account of the great distances which separate them, this cause could only have been a fluid of immense extent. In order to have communicated to these bodies in the same direction an almost circular motion around the sun this fluid must have surrounded the sun like an atmosphere.

The consideration of the planetary motions leads us, therefore, to *suppose* that, in consequence of an excessive heat, the atmosphere of the sun has in former times extended beyond the orbits of all the planets, and that it has successively contracted up to its present limits.

In the primitive state which we suppose the sun to have had, it resembled those nebulæ which the telescope shows us, composed of a more or less brilliant nucleus, surrounded by a nebulosity which, by condensing towards the surface of the nucleus, transforms it into a star. If, by analogy, he says, we conceive all the stars to have been formed in this manner, we may imagine their anterior state of nebulosity, preceded itself by other states in which the nebulous matter was more and more diffused, the nucleus being less and less luminous. By thus going back as far as possible, we may arrive in thought at a degree of nebulosity so diffused, that we can scarcely conceive of its existence.

For a long time the particular arrangement of certain stars, visible to ordinary sight, has struck the attention of philosophical observers. Mitchell has already remarked how

little probability there is that the stars of the Pleiades, for example, have been contracted into the narrow space which encloses them by chance alone; and he has concluded that this group of stars, and similar groups which the heavens present, are the effects of some primitive cause or of some *general law* of nature.

These groups are a necessary result of the condensation of the nebulæ into several nuclei; for it is evident that the nebulous matter, being constantly attracted by these different nuclei, ought to form at length a group of stars like that of the Pleiades. The condensation of nubulæ into two nuclei would form in like manner a pair of close stars revolving about each other, such as the binary stars, whose relative motions have been already recognized.

But how has the solar atmosphere determined the motions of rotation and revolution of the planets and satellites? If these bodies had penetrated deeply within this atmosphere, its resistance would have caused them to fall into the sun. We may, therefore, *conjecture* that the planets have been formed at the successive *centrifugal limits* of the solar atmosphere, by the condensation of the zones of vapor which, in cooling, it has been obliged to abandon in the plane of its equator.

Let us recall, says La Place, the results which we have given in the tenth chapter of the preceding book. [He refers to the "*Exposition du Systeme du Monde.*"]

The atmosphere of the sun, he says, could not extend outward indefinitely. Its limit is the point where the centrifugal force, due to its motion of rotation, balances gravity. Now, in proportion as its cooling causes the atmosphere to contract and to be condensed towards the sun's surface, the motion of rotation *must increase*. For, by virtue of the principle of areas, the sum of the areas described by the radius-vector of each molecule of the sun and of its atmosphere, when projected on the plane of his equator, being always the same, the rotation ought to be more rapid when these molecules are brought nearer the sun's centre. The centrifugal force, due to this increased motion, thus becoming greater, the point at which gravity is equal to it approaches nearer the sun's centre

By *supposing*, therefore, what it is very natural to admit,

that the sun's atmosphere, at any epoch, had extended up to this *limit* (where the gravitation and centrifugal forces were equal,) it would be necessary, on further cooling, for the atmosphere to abandon the molecules situated at this *limit*, and at the *successive limits* produced by the increase of the sun's rotation.

These molecules, thus abandoned, have continued to circulate around the sun, in the same direction as before, since their centrifugal force was just balanced by their gravity towards the sun.

But this equality of centrifugal force and gravity not taking place with regard to the atmospheric molecules placed on the parallels to the solar equator, these latter molecules by their gravity will follow the atmosphere in proportion as it is condensed, and they will not cease to belong to it, until by their motion they have reached the equator.

Let us consider now, says La Place, the zones of vapor successively abandoned. These zones ought, most probably, to form, by their condensation, and the mutual attraction of their molecules, various concentric rings of vapor, revolving around the sun. The mutual friction of the molecules of each ring ought to accelerate those moving more slowly, and retard the swifter, until they should all have acquired the same *angular* motion about the sun. Hence the *real velocity* of the molecules *farthest from the sun* will be the *greatest*. The following cause ought to contribute also to this difference of velocity. The molecules of the ring most distant from the sun, and which, by the effect of cooling and condensing, are brought nearer so as to form the outer portion of the ring, have always described areas proportional to the time, since the central force by which they are animated has been constantly directed towards the sun's centre.

Now this constancy of areas requires an increase of velocity in proportion as they approach the centre of motion. It is evident that the same cause ought to diminish the velocity of those molecules which, by the cooling and contracting process, are carried outwards to form the inner part of the ring.

If all the molecules of one of these vaporous rings had continued to condense without separating, they would have formed at last a liquid or a solid ring.

But the regularity which such a formation requires in all parts of the ring, and in their rate of cooling, ought to render this phenomenon extremely rare.

Hence the solar system offers but a single example of it; namely that of the rings of Saturn. Almost always each vaporous ring ought to be broken into several masses which, moving with nearly the same velocity, have continued to revolve around the sun at the same distance from him. These masses ought each one to take on a spheroidal form, with a motion of rotation in the same direction as their motion of revolution around the sun, since their molecules nearest to him had less velocity than those farthest from him. They must, therefore, have formed so many planets in a vaporous condition. But if one of them had been large and powerful enough to successively re-unite by its attraction all the others around its own centre, the vaporous ring will have been thus transformed into a single spheroidal vaporous mass, revolving around the sun, nearly in the plane of his equator, with a nearly circular orbit, and with its motion of rotation generally in the same direction with that of its revolution around the sun. This last case has been the most common; but the solar system offers to us an example of the first case, in the four small planets revolving between Mars and Jupiter, unless we suppose with Olbers that they formed at first a single planet which some strong explosion has divided into several parts animated by different velocities. [There are now 276 of these bodies known to astronomers.]

If now we follow, says La Place, the changes which further cooling ought to produce in the planets consisting of vapor, the formation of which we have just considered, we shall see a nucleus begin at the centre of each of them, and see it grow continually by the condensation of the atmosphere which surrounds it. In this state the planet perfectly resembles the sun in the nebulous condition which we have been considering. Its cooling ought therefore to produce, at the different *centrifugal limits* of its atmosphere, phenomena similar to those which we have described, that is to say rings and satellites revolving around its centre in the direction of its motion of rotation, and the satellites rotating also in the same direction on their axes.

The regular distribution of the mass of Saturn's rings around his centre, and in the plane of his equator, results naturally from this hypothesis, and, without it, becomes inexplicable. These rings appear to me, says La Place, to be the ever existing *proof* of the former extension of Saturn's atmosphere, and of its successive contractions.

Thus, the singular phenomena of the small eccentricities of the orbit of the several planets, and those of their satellites, or their almost circular orbits, the small inclinations of these orbits to the sun's equator, and the identity of the motions of rotation and revolution of all these bodies with that of the sun's rotation, flow from the hypothesis which we propose, and give to it a *great probability*, which may be still further increased by the following considerations:

All the bodies which revolve around a planet, having been formed, according to this hypothesis, by the zones which its atmosphere has successively abandoned, and the planet's motion of rotation having become more and more rapid, the duration of this rotation ought to be less than those of the revolution of these different bodies. This must be true, likewise, for the sun in comparison with the planets. All this, says La Place, is confirmed by observation. The duration of revolution of Saturn's nearest ring is, according to Herschel's observations, 0.438*d*, and that of Saturn's rotation is 0.427*d*. The difference, 0.011*d*, is small, as it ought to be; because the part of Saturn's atmosphere which the loss of heat has condensed upon the planet's surface since the formation of this ring, being small, and coming from a small height, it ought to have produced but a small increase of the planet's rotation.

If the solar system had been formed with perfect regularity, the orbits of the bodies which compose it would have been perfect circles, whose planes, as well as those of the different equators and rings, would have coincided exactly with the sun's equator. But we can conceive that the innumerable varieties, which ought to have prevailed in the temperature and density of the several parts of these great masses, have produced the eccentricities of their orbits, and the deviations of their motions from the plane of the sun's equator.

In our hypothesis, the comets are *strangers* to the planetary system. Considering them, as we have done, as small

nebulæ wandering from one solar system to another, and formed by the condensation of nebulous matter so profusely scattered throughout the universe, it is evident that when they arrive at that part of space where the sun's attraction predominates, he compels them to describe elliptical or hyperbolic orbits. But their velocities being equally possible in all directions, they ought to move indifferently in all directions and under all inclinations to the ecliptic, which is comformable to observation. Thus the condensation of nebulous matter, by which we have explained the motions of rotation and revolution of the planets and satellites in the same direction and in planes of small inclination to each other, explains equally why the comets depart from this general law.

In some eight or nine pages more La Place goes on to strengthen the argument for his theory, and especially to show why the satellites could not form similar rings, and satellites of satellites. But the gist of his theory is now before us.

It will be noticed that he does not explain how the variety of temperature and density of the several parts of a large ring produced the eccentricities of the planetary orbits, nor the deviations of the planes of the orbits from that of the sun's equator, nor the deviations of their equators from the planes of their orbits. He returns to the subject again, and suggests the possibility of the collisions of comets with the planets as the cause of these deviations. But, if the rings had considerable breadth and thickness, and were not homogeneous, as is probable, then they might separate in planes slightly different from the solar equator, but parallel to it, and also into parts at slightly different distances from the sun's centre. Then, when by their mutual attraction they were brought to unite, it would be with a more or less oblique collision, sufficient perhaps to account for all the observed deviations.

In accounting for the fact that the satellites rotate in the same time as that of their revolution about their planets, La Place uses reasoning that is equivalent to the more modern theory of tidal retardations of a planet's rotation. This tidal retardation is perhaps the cause that the planet Mars takes so much more time to rotate on his axis than

his nearest satellite does to revolve around him. I find the tidal action of the sun on Mars to be at least one-third greater than it is on the Earth, notwithstanding the greater distance of Mars, because of his small mass for counteracting the sun's tidal action.

Soon after the ring, which formed the nearest satellite of Mars, was separated from him, his diameter must have been, including his atmosphere, larger than the present diameter of the earth, or considerably more than double the present diameter of Mars. The effect of this would be to more than double the sun's tidal action on Mars, or make it equal to the moon's present tidal action on the waters of the earth. It was perhaps mostly at that distant epoch that this tidal retardation gradually reduced the time of rotation of Mars, without affecting the revolution of his satellites.

Perhaps the most plausible objection to La Place's hypothesis is that stated in Professor Newcomb's Popular Astronomy. The author of that objection claims that, instead of a few widely separated rings being detached at the centrifugal limits of the sun's equator, there ought to be a continuous succession, without any interval between them, of such rings, forming one broad flat disc, extending from the orbit of Neptune to the sun's present surface. But whoever was the author of this objection, it seems to me, failed to appreciate what La Place had proved as to the necessary ratio of 3 to 2 of the equatorial to the polar radius of the sun's atmosphere, at the moment of reaching the *centrifugal limit.* This greatest ratio is *only reached* at the moment the ring is about to separate. Immediatley afterwards the lower height of the equatorial surface of the atmosphere *diminishes the centrifugal force*, and at the same time *increases gravity*. The equilibrium figure of the atmosphere becomes at once less eccentric, and approaches the sphere more nearly. Moreover, the loss of the *ring's mass*, and of the *great amount of area* which it had contributed towards the constant sum, has *greatly* changed that constant. A new and a smaller constant for the sum of the areas now governs the sun's rotation. If, therefore, it was necessary, upon contraction, to maintain the *larger constant* by an increase of areal rotation, it is evident that the *smaller constant* may not demand sufficient increase of rotation to re-establish the centrifugal limit until after a very long interval of time.

Besides, after the first planet, say Neptune, was fully formed, he began to exercise a powerful tidal action upon the sun, and upon his rate of rotation. Remembering that tidal action upon any body is proportioned, other things being equal, to the *diameter* of the body acted upon, we may easily realize what a gigantic tide Neptune would raise on the sun, when his diameter was little inferior to the diameter of Neptune's orbit.

This tidal retardation of the sun's rotation would go largely towards neutralizing the acceleration demanded by his contraction. Hence the period of the next centrifugal limit would be adjourned to a very distant epoch. The same reasoning will apply, with greater or less force, to the planets that are formed subsequently.

If the views were correct of those who maintain that the centrifugal limits ought to be continuous, and without interval of any kind, then the present shape of the sun ought to show the ratio of his equatorial to his polar diameter as 3 to 2.

But it is well known that observation shows no appreciable difference in the sun's diameters at present. Hence he is far from being in the condition required for the centrifugal limit.

In the paper on "A New Cosmogony," published in *Nature* on the 4th of August last, it is objected to La Place's theory of the formation of the planets from the broken rings, that "two opposite portions of a ring of the dimensions of Neptune's orbit could scarcely come together in less than 150,000,000 years." The writer justly adds: "It must be admitted that this is a startling demand on the time-exchequer even of the cosmos."

How this computation of 150,000,000 years was made I do not know. But I have made the following computation, with very different results: Suppose the planet Neptune to be at a certain point in its orbit, and a particle of matter at the opposite extremity of a diameter of the same orbit, how long would it take for the planet to attract this particle to its surface?

It is comparatively a simple problem of the differential and integral calculus, applied to the law of gravitation and the known mass of the planet. The result which I found is, that

it will take less than 6,000 years to bring the particle in a straight line to the planet. If the particle has to describe the semi-circumference of the orbit, instead of the diameter, then the time would be less than 9,000 years. The revolution of both bodies around the sun, in nearly the same orbit, could by no means prolong the event from the neighborhood of 10,000 years to 150,000,000 years.

In conclusion, it may be asked, Is La Place's nebular hypothesis true? To this question I would answer, it may be true, or it may not be true. But it is by far the most beautiful and the most philosophical theory of the *process of creation* for a solar system like that to which we belong, that has ever yet been proposed.

This theory does not, as some suppose, do away with the necessity of an intelligent Creator and Designer of the universe. That cannot be done until we discover how, without such a Creator, the law of gravitation, and other similar laws of nature, may be imposed upon inert matter.

THE AGE OF THE STARS.*

We may assume in a general manner that when a sun is formed, other things being equal, the higher its temperature is raised the more effectively and the longer will it fulfil the functions of a radiating body.

It is true that the constitution of these celestial bodies is not sufficiently known for us to distinguish certainly the conditions which complicate these simple and general data, but we must not stop on account of these difficulties. Let us say that the age of the stars depends upon the temperature of their matter.

But this temperature reveals itself in the character of the spectrum. That wonderful prismatic image which shows us the collection of rays which a star sends us, separated, classified, arranged, and from which we know how to-day to read the chemical composition, motion, and many other precious data, instructs us also in regard to the temperature.

* Extract from an address delivered at the annual public session of the five Academies of France, Oct. 25, 1887, by M. Janssen, director of the Observatory at Meudon, France.

If the body is simply heated without being raised to incandescence, its spectrum informs us of this circumstance by the absence of those rays which give us the sensation of light. But when incandescence is produced, the luminous and photographic rays show themselves. When this becomes still more pronounced the spectrum is enriched on the side of the violet, which is always an indication of high temperature. If the temperature becomes still higher, the violet and the invisible rays which follow then become more abundant. One may conceive, abstractly, of a body which shall be raised to such a temperature that it will emit only those invisible rays situated beyond the violet, which the eye no longer perceives, and which are only revealed by photography, fluorescence, or thermoscopic apparatus. Thus, in the increasing scale of temperature, the body is first not visible, then becomes visible, and again ceases to be, by excess of the same temperature.

The spectrum faithfully shows all these states, and permits us to read, with wonderful fidelity, the most delicate circumstance.

In applying these facts we assume that the temperature of a star, or, at all events, the temperature of the exterior envelopes, will be higher in proportion as its spectrum is richer in violet rays.

There exists in the sky a great number of stars whose spectra are developed toward the violet side. These are generally the ones whose light appears white or bluish. The most remarkable is that magnificent star, Sirius, which, in the amount of light which it sends us, is without equal in the sky. The volume of this star is enormous and incomparably greater than that of our sun. It is enveloped in a vast atmosphere of hydrogen, so far as its spectrum shows. It contains, without doubt, other metals, but the presence of these is difficult to prove, doubtless because of the power itself of radiation of the vapors of those metals. Every thing indicates here, according to our theory, a sun in all the power of its activity, and which will conserve this activity during immense periods of time.

After Sirius, which is the ornament of our sky, and which will continue for a long time, according to the indications of science, we find as a star surrounded by a vast atmosphere

of hydrogen, the star Vega of the constellation Lyra. This is a white star which we often notice in the zenithal regions of our sky. We suppose that the mass of this sun is raised to a high temperature, and that it has before it long spaces of activity and radiation.

These two examples of stars in the full development of their solar activity, are perhaps the most remarkable, but they are not the only ones. There are a considerable number of stars in the sky belonging to this class. We may say even that the greater number of stars visible to the naked eye are in this condition. But we discover at the same time another class of stars in which the character of the spectrum indicates a degree of condensation a good deal more advanced. In place of the vast atmosphere of hydrogen the analysis shows a gaseous covering, lower, more dense, formed of those metallic vapors which we recognize precisely in our sun, for our central body belongs to that class of stars whose solar functions seem still powerful, but which, however, have passed what we may call their *youth*, if you will permit me this expression. It is to be remarked that, in general, the color of these stars is found to be in accord with their constitution. They do not have that brilliancy, that whiteness, which characterizes stars of the first class. Some of them are of a yellow or even orange color.

Let us take as examples of those stars which have passed the period of their most active radiation, first our sun, as I have already said above, then Aldebaran or the Eye of the Bull, which is in the path of the sun and which shines in winter above the celebrated constellations of Orion; Arcturus, the beautiful star in Boötes, which is found in the prolongation of the stars of the Great Bear, and whose red rays declare the evolution already far advanced.

But there are again some stars which have come to a more pronounced degree of their sidereal evolution. Here the spectrum shows signs of a fatal cooling. The violet, the color of high temperature, vanishes here almost absolutely; at the same time some dark bands, indices of an atmosphere dense and cold, where chemical affinities have already commenced their work of association, invade the spectrum. It is to be remarked that the colors of these stars correspond in general to those conditions supposed to be the signs of decrepitude; they become deep orange and pass often to dark red.

Such are the first results of a study which is only begun. I have tried to present it in its simplicity, to avoid the difficulties, the objections, which legitimately arise in its application. I am persuaded that Science will triumph over these difficulties as it has triumphed over difficulties much more considerable, and that the general bases of the method will be definitely established.

AN AUTOMATIC TRANSIT INSTRUMENT.

PROF. FRANK H. BIGELOW.*

FOR THE MESSENGER.

The drift of practical astronomy in the observation of the coördinates of right ascension and declination appears to be setting in the direction of eliminating the personal equation of the observer, by the substitution of some sort of an automatic contrivance. The experience of twenty-five years has lead to the conclusion that the errors arising out of the physiological constitution cannot be controlled by the power of the will, and that an uncertain margin of one-seventh of a second shadows like a penumbra the exact truth that is sought. Clearly if a method can be devised that will measure precisely the facts, we shall be relieved of the necessity of falling back upon the mean result of many observations, and thereby save enormous sums of money now expended in the computations of transits, for which reason the cost to be incurred in the first outlay upon instruments will ultimately become an economical appropriation.

Several attempts have been already made by instrument makers to accomplish this object, but as yet apparently with no satisfaction, so that any suggestion looking to this end, even if imperfect, will be acceptable. In the *Astron. Nach.* No. 2828, J. Repsold, Hamburg, communicates the theory of an automatic apparatus depending upon the instant of mechanical contact between a moving knob, attached to the transit which swings through short hour-angle arcs, and a stationary button, the record being made on the chronograph. The objection is mentioned that the conversion of a fixed instrument into a movable one is liable to substitute other errors for that of the personal equation.

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* Racine College, Wisconsin.

It is, however, to photographic processes that we must turn for help in this emergency, and the success already acquired in other directions ought not to lead to disappointment when applied to transits. The main difficulty has been that bromide paper is not sensitive enough to receive the trails and contacts with sufficient rapidity, and hence the first improvement must come in at this point. It is not likely that the instantaneousness of any process can excel that of the human retina as a receiver, but since the eye is only a transmitter, the photograph gains all the advantages of a primary over a secondary effect. Probably all increase in speed above one-tenth of a second can be claimed as an improvement, while it may not be unreasonable to suppose that one three-thousandth of a second will yet be faithfully recorded. At all events the first question is to secure the utmost sensitiveness of impression, and the second is to have the conditions under perfect mechanical control. The attainment of sensitiveness, doubtless depends upon the employment of the gelatine dry process on glass, because none of the paper preparations can compete with it.

I feel some hesitation in making the following theoretical suggestions, hoping that experiments available to others may put them to the test. The dimensions here given may need modification, although the best meridian circles have been kept in mind in the endeavors to fit an apparatus to them. Suppose instead of plate glass for the photograph, we use a thin symmetrical cylinder of two inches radius, the glass being one-fifteenth of an inch thick, prepared on the outer surface by the best dry process, beyond which we can do nothing for sensitiveness. Mount this as a chronograph barrel on a skeleton frame, one end of which is prominent, the other removable by thumb screws, so that it may revolve concentric to an axis. At one extremity this connects with the final wheel of a clock train by an endless screw or cogs, to be disconnected at will, the first half of the axis being squared and smooth for sliding, and the second with a screw cut for advancing the barrel attached to it by clamp, terminating in a slot on the box. At mid length the axis must be broken, the screw end penetrating as a round pinion into the other part. The whole fits into a rectangular dark box and is to be lifted in and out from end rests, the opening being on

a long side. One of its lower short face edges has a hinge and counterpoise weight for turning it through a right angle when desired. On the centre of the upper side is a little cell, holding an electric spark that will send light through a slit with adjustable jaws, at right angles to the star trail, on strokes from the standard clock. On the third side in the same helix, ninety degrees from the spark hole, enters the emergent pencil from the telescope, continuously trailing, except when eclipsed by a thread or obstruction, so that the spark acts fifteen seconds in advance of the pencil, on the supposition that the barrel revolves once a minute.

Attention should be called to the facility that this arrangement offers for the enlargement of the negative to any required scale, in order to make a copy on paper for reading and permanent record. After developing, place the cylinder on a circle of equal radius, and on a larger eccentric circle put the paper for copy inside a similar cylinder. In the common axis arrange an incandescent light of sufficient length to illuminate the whole in cross sections, and the diverging radii unless some parallactic blurring from the thickness of the wire modifies the action, will produce an accurate enlarged copy that can be readily translated. The glass cylinder may be washed, and it will then be ready for a repetition of its functions.

The next question concerns the position of the photochronograph, referred to the eye end of the telescope. It is apparent that the lenses must be figured for the actinic rays, and that this implies a loss of visual power for direct seeing. There seems to be no way to compromise the matter if the same tube is to be used, and it is therefore proposed to employ two tubes, one for seeing and one for photographing, both attached to the same cube, now elongated to a parallelopiped, and having the axes of collimation theoretically parallel. The changes in the auxiliary parts of the instrument need be very slight, the telescopes being set about three inches from the middle of the axis towards the pivots, the circles, counterpoises, clamps and handles, the reversing shoulders all being disposed without crowding as in the standard Repsold meridian circle. This telescope is in all respects fitted for chronograph signals, eye and ear transits and measures of declination. The adjustments to the

meridian and equator follow the prescribed methods, corrected to include the eccentric position.

The parallel photographic telescope is bent in the cube by a forty-five degree prism or a mirror as thought best, the reticle being located on the end of the pivot, and a counterpoise weight maintaining an equilibrium of the moments of rotation. Screwed upon the pivot is the eye piece almost touching the eye, so that the emergent pencil, if perfectly adjusted to the axis, is stationary in the rotation of the telescope, or else describes a small circle about it; but since the reticle rotates at the same time the transits are subject only to the error of collimation and deviation from the meridian. This enables us to place the photo-chronograph on the upper surface of the pier, between the end of the axis and the counterpoise standards, where it will have a steady yet adjustable position. A hole for the clock work attached to the chronograph is cut in each pier, but it may be found that the vibrations are injurious, and in that case a secondary stand can be set up in the neighborhood. The hinge mentioned above allows the chronograph to be tipped up so as to withdraw the barrel, and also to leave free space to introduce a compensating and collimating eye piece at right angles to the rotation axis. In taking the instrumental errors the same level applies to both telescopes, the same mercury basin viewed in one from a ladder and in the other from the pier head; but two sets of fixed collimators would be required. It is not supposed that difficulties which cannot be met will arise from the additional weight on the cube, as regards flexure. This method is superior to any combination that implies placing the chronograph on the swinging end of the telescope, both for technical reasons and for convenience.

The time telescope system opens the possibility of interesting comparison observations, since the observer is in full possession of the old methods, while the new may go on simultaneously upon the same star. The personal equation can be determined upon such bright stars as the photograph will record, and the correction may then be applied to the whole list. Uncertainties will be avoided in the comparison of stars taken under such widely different circumstances as appear in the current methods employed in the detection of

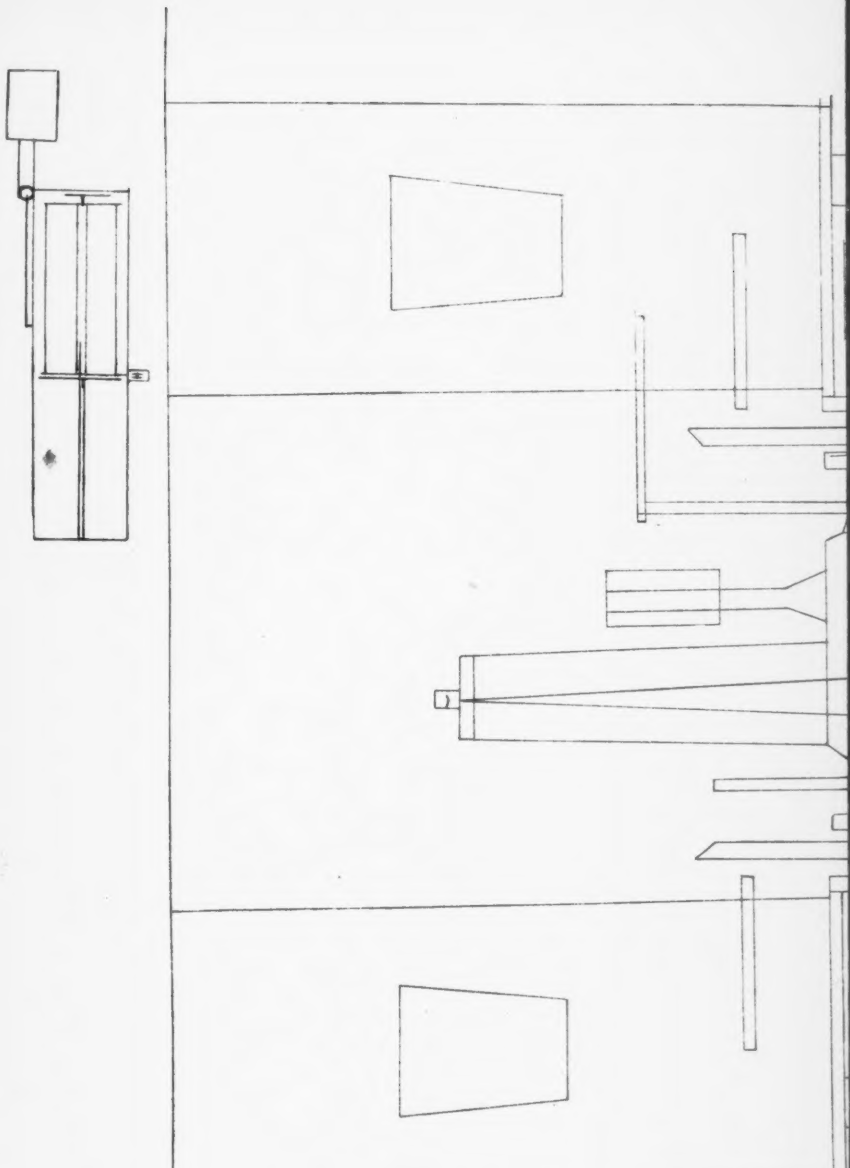
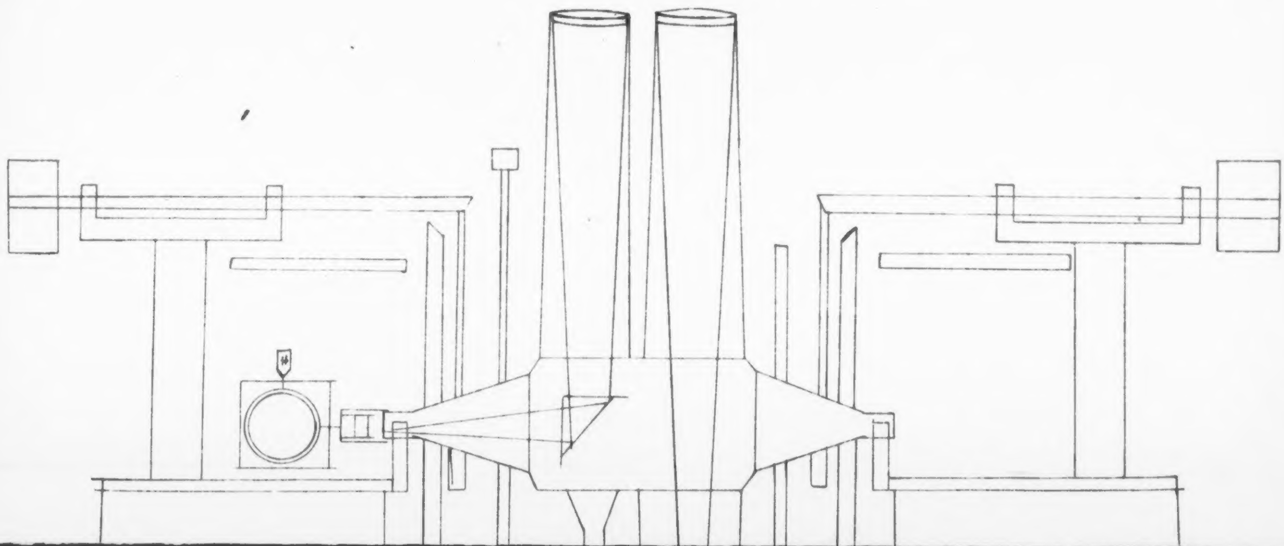


Illustration of an Automatic Transit Instrument.



the personal error. It will probably be conceded that the effectiveness of the meridian circle will be in no wise diminished, while all the advantages offered by the use of photography can be controlled to a great degree of sensitiveness.

FOR STUDENTS AND YOUNG OBSERVERS.

Interesting Phenomena for May.

THE PLANETS.

Mercury's path for the month of May is through the constellations of Taurus, Orion and Gemini. He is in superior conjunction with the sun May 10th, at 7 o'clock in the evening, and at the end of the month he is only a few degrees east of the sun. On the 9th he passes to the north side of the ecliptic; on the 14th is in perhelion and on the 24th is in greatest heliocentric latitude north.

Venus is passing through Aries and Taurus; May 8th the planet is in conjunction with the moon, and will be within a degree of Neptune on the last day of the month. Its angular diameter a little less than 5″ and diminishing, as is also the brilliancy of its disc.

Mars, doubtless, has been noticed during the last month by the most casual of observers. His nearest approach to the earth for this year, and full disc towards us were the causes for his unusual ruddy appearance. Mr. Keeler, assistant at Lick Observatory, writes under date of April 10th, that the satellites of Mars are remarkably bright in the great 36-inch lens even without a bar to hide the planet. He thinks they may be followed at Lick Observatory for a large part of the year.

Jupiter is an evening object for the present month, and is retrograding. He will move to the westward, 3° during May, will be in quadrature with the sun 21st, and in conjunction with the moon on the 24th. His polar diameter is 21.6″, but his position in south declination makes his meridian atlitude low in northern latitude, and hence not favorable for observation.

Saturn passes the meridian at about 9 o'clock during this month, but is in more than 20° north declination, so that the planet may be observed in the evening fairly well.

It is in the constellation of Cancer and still makes a triangle with bright stars in Gemini, that has been noticed for months past.

Uranus at the beginning of May is very near to Mars. On the 5th it will be only 30′ directly north of the latter planet. The opera glass will show Uranus well.

Neptune is in Taurus a few degrees south of the Pleiades.

	R. A. h m	Decl.	Rises. h m	Transits. h m	Sets. h m
NEPTUNE.					
May 5	3 49.4	+18°24′	5 33 A. M.	12 53.2 P. M.	8 13 P. M.
15	3 51.0	+18 29	4 55 "	12 15.4 "	7 36 "
25	3 52.5	+18 34	4 13 "	11 33.8 A. M.	6 54 "
SATURN.					
May 5	8 12.2	+20 35	9 45 A. M.	5 15.3 P. M.	12 45 A. M.
15	8 15.1	+20 27	9 09 "	4 38.9 "	12 08 "
25	8 18.5	+20 16	8 34 "	4 02.9 "	11 32 "
MARS.					
May 5	12 52.1	−4 17	4 08 P. M.	9 54.3 P. M.	3 41 A. M.
15	12 46.0	−4 07	3 22 "	9 08.8 "	2 56 "
25	12 44.8	−4 25	2 42 "	8 28.4 "	2 15 "
URANUS.					
May 5	12 52.4	−4 52	4 10 P. M.	9 54.6 P. M.	3 39 A. M.
15	12 51.2	−4 45	3 29 "	9 14.1 "	2 58 "
25	12 50.4	−4 40	2 49 "	8 34.0 "	2 19 "
JUPITER.					
May 5	16 06.6	−19 53	8 28 P. M.	1 08.2 A. M.	5 49 A. M.
15	16 01.8	−19 39	7 42 "	12 23.9 "	5 06 "
25	15 56.5	−19 25	6 56 "	11 39.3 "	4 22 "
VENUS.					
May 6	1 49.1	+9 42	4 07 A. M.	10 49.1 A. M.	5 32 P. M.
16	2 36.0	+13 58	3 56 "	10 56.6 "	5 57 "
26	3 24.5	+17 42	3 49 "	11 05.7 "	6 22 "
MERCURY.					
May 6	2 37.2	+14 42	4 34 A. M.	11 37.2 A. M.	6 40 P. M.
16	4 03.9	+21 52	4 48 "	12 24.4 P. M.	8 01 "
26	5 29.9	+25 23	5 15 "	1 10.9 "	9 06 "
THE SUN.					
May 6	2 56.7	+16 49	4 44 A. M.	11 56.4 A. M.	7 09 P. M.
16	3 35.7	+19 19	4 32 "	11 56.2 "	7 21 "
26	4 15.8	+21 18	4 23 "	11 56.9 "	7 31 "

Occultations Visible at Washington.

Date.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean T. h m	IMMERSION. Angle f'm N. Point. °	EMERSION. Wash. Mean T. h m	EMERSION. Angle f'm N. P't. °	Duration. h m
May 16	θ Cancri	5½	10 22	195	Star 1.4′ S. of moon's limb.		
19	B. A. C. 3837	6½	11 14	61	11 52	349	0 37
23	ξ^1 Libræ	6	9 37	47	10 02	8	0 25
24	θ Libræ	4½	9 41	204	Star 7.1′ S. of moon's limb.		
24	49 Libræ	6	12 50	18	Star 5.7′ N. of moon's limb.		
27	o Sagittarii	3½	9 42	104	10 46	272	1 04

Phases of the Moon.

		Central Time. d	h m
Last Quarter	May	2,	5 47.1 P. M.
New Moon		10,	7 23.5 "
First Quarter		18,	5 05.2 "
Full Moon		25,	7 40.1 A. M.

Great Red Spot on Jupiter—Times when its Zero Meridian Passes the Centre of Jupiter's Disc.

	Central Time. d	h m		Central Time. d	h m		Central Time. d	h m
May	2,	12 58.7 A. M.	May	12,	7 03.7 P. M.	May	23,	11 04.7 P. M.
	2,	6 49.7 P. M.		14,	12 50.6 A. M.		24,	6 55.8 "
	4,	2 36.6 A. M.		14,	8 41.7 P. M.		26,	12 42.7 A. M.
	4,	10 27.7 P. M.		16,	2 28.5 A. M.		26,	8 33.7 P. M.
	5,	6 18.8 "		16,	10 19.6 P. M.		28,	2 20.6 A. M.
	7,	12 05.7 A. M.		18,	4 06.5 A. M.		28,	10 11.7 P. M.
	7,	7 56.8 P. M.		18,	11 57.6 P. M.		30,	3 58.6 A. M.
	9,	1 43.6 A. M.		19,	7 48.7 "		30,	11 49.8 P. M.
	9,	9 34.7 P. M.		21,	1 35.6 A. M.		31,	7 40.9 "
	11,	3 21.5 A. M.		21,	9 26.6 P. M.			
	11,	11 12.6 P. M.		23,	3 13.5 A. M.			

Phenomena of Jupiter's Satellites.

	Central Time. d	h m				Central Time. d	h m		
May	1,	4 25 A. M.	II	Ec. Dis.	May	18,	4 53 A. M.	II	Tr. In.
	3,	3 06 "	III	Sh. In.		19,	10 54 P. M.	II	Ec. Dis.
	3,	4 58 "	III	Sh. Eg.		20,	1 25 A. M.	II	Oc. Re.
	3,	5 06 "	III	Tr. In.		21,	1 22 "	III	Ec. Dis.
	3,	11 31 P. M.	II	Sh. In.		21,	3 03 "	III	Oc. Re.
	4,	12 24 A. M.	II	Tr. In.		21,	8 26 P. M.	II	Tr. Eg.
	4,	2 01 "	II	Sh. Eg.		21,	8 28 "	II	Sh. Eg.
	4,	2 49 "	II	Tr. Eg.		22,	2 16 A. M.	I	Oc. Dis.
	5,	8 54 P. M.	II	Oc. Re.		22,	4 28 "	I	Oc. Re.
	6,	4 04 A. M.	I	Ec. Dis.		22,	11 23 P. M.	I	Tr. In.
	6,	8 27 P. M.	III	Oc. Re.		22,	11 24 "	I	Sh. In.
	7,	1 07 A. M.	I	Sh. In.		23,	1 35 A. M.	I	Tr. Eg.
	7,	1 30 "	I	Tr. In.		23,	1 37 "	I	Sh. Eg.
	7,	3 20 "	I	Sh. Eg.		23,	8 42 "	I	Oc. Dis.
	7,	3 41 "	I	Tr. Eg.		23,	10 55 P. M.	I	Ec. Re.
	7,	10 30 P. M.	I	Ec. Dis.		24,	8 01 "	I	Tr. Eg.
	8,	1 00 A. M.	I	Oc. Re.		24,	8 05 "	I	Sh. Eg.
	8,	7 56 P. M.	I	Tr. In.		27,	1 13 A. M.	II	Oc. Dis.
	8,	9 49 "	I	Sh. Eg.		27,	3 54 "	II	Ec. Re.
	8,	10 07 "	I	Tr. Eg.		27,	4 47 "	III	Oc. Dis.
	11,	2 05 A. M.	II	Sh. In.		28,	8 13 P. M.	II	Tr. In.
	11,	2 39 "	II	Tr. In.		28,	8 32 "	II	Sh. In.
	11,	4 35 "	II	Sh. Eg.		28,	10 40 "	II	Tr. Eg.
	11,	5 05 "	II	Tr. Eg.		28,	11 03 "	II	Sh. Eg.
	12,	8 18 P. M.	II	Ec. Dis.		29,	4 00 A. M.	I	Oc. Dis.
	12,	11 10 "	II	Oc. Re.		30,	1 07 "	I	Tr. In.
	13,	9 24 "	III	Ec. Dis.		30,	1 19 "	I	Sh. In.
	13,	11 45 "	III	Oc. Re.		30,	3 19 "	I	Tr. Eg.
	14,	3 01 A. M.	I	Sh. In.		30,	3 31 "	I	Sh. Eg.
	14,	3 14 "	I	Tr. In.		30,	10 26 P. M.	I	Oc. Dis.
	15,	12 24 "	I	Ec. Dis.		31,	12 49 A. M.	I	Ec. Re.
	15,	2 44 "	I	Oc. Re.		31,	7 33 P. M.	I	Tr. In.
	15,	9 30 P. M.	I	Sh. In.		31,	7 47 "	I	Sh. In.
	15,	9 40 "	I	Tr. In.		31,	7 47 "	III	Tr. Eg.
	15,	11 43 "	I	Sh. Eg.		31,	8 54 "	III	Sh. Eg.
	15,	11 51 "	I	Tr. Eg.		31,	9 45 "	I	Tr. Eg.
	16,	9 10 "	I	Oc. Re.		31,	9 59 "	I	Sh. Eg.
	18,	4 40 A. M.	II	Sh. In.					

New Minor Planet No. (274) was discovered by Palisa April 3.4211 Gr. M. T. R. A. 12*h* 50*m* 39.5*s*. Decl. north 0° 50′ 50″. Daily motion —48*s*; south 5′. It is 13th magnitude.

New Minor Planet No. (275) was found by Palisa, April 15.5120 Gr. M. T. R. A. 12*h* 39*m* 4*s*. Decl. north 3°29′. Daily motion —40*s*; south 4′. Eleventh magnitude.

New Minor Planet No. (276), also eleventh magnitude was discovered by Palisa April 17.5287. R. A. 14*h* 4*m* 0.8*s*. Decl. 12°34′51″ south. Daily motion —44*s*; south 11′.

Portable Transit Observations. I was much interested in the article published in No. 27 of THE MESSENGER, page 209, "How Time Observations are Taken with a Small Transit at Carleton College Observatory." In using this method it is not necessary to know the value of the azimuth and collimation errors, but their signs must be known.

In the writer's Observatory the transit pier stands in an adobe soil which shrinks and swells with every change from wet to dry weather. The azimuth error has changed on this account from + 2*s* to — 35*s*, and no reliance can be placed on its constancy. There is not sufficient distance for a meridian mark and it is evident that a collimator would be useless on such ground.

By simplifying the method above referred to, the time is taken, and the clock correction examined without knowing either the value or sign of the azimuth errors, but is only available for use with a portable transit which can be quickly used. It is necessary to have a large number of stars to select from. Those in the American Ephemeris and Berliner Jahrbuch will answer.

Method. Find the A factors of all those stars situated between 20° N. Z. D. and 41° S. Z. D., and arrange all the N. Z. D. stars in one column and the S. Z. D. stars in another. Now at the time of observation let us take a star having a certain A factor and, after observing half the wires, reverse the transit and observe the same wires again (which eliminates the collimation error); then take another star on the opposite side of the zenith having nearly the same A value, observe and reverse as before. It is evident that the mean

of the two observations will be the true time, and the difference between either star and the mean of the two divided by A will give the error of azimuth, which may be adopted as a provisional value in case the time is found by a single star before using another set. Such sets will be frequently found if both the American and Berliner Ephemerides are used, and should be tabulated for future reference. This method will be found the shortest way for getting true time from unstable transit piers. It should be mentioned that the level error is applied as usual. The following example will illustrate the meaning:

Star.	A.	Decl	
ζ Tauri,	.31	+ 21°04′	Time set.
υ Aurigæ,	.31	+ 49 46	

March 3, 1888.

	ζ Tauri, B. J.		υ Aurigæ, B. J.
	E.		E.
	h m s		h m s
	5 30 52.5		5 36 26.5
	31 26.7		37 15.5
	W.		W.
	5 32 33.8		5 38 52.0
	33 07.8		5 39 41.3
	5 32 00.2		5 38 03.82
Level corr.	—00.42	Level corr.	— 00.80
	5 31 59.78		5 38 03.92
R. A.	5 30 57.01	R. A.	5 37 37.46
	1 02.77 fast.		49.56 fast.
	49.56		
Mean	56.16		(56.16—49.56) ÷ .31 = 21.32*s* azimuth.

This method has been proved by comparing the clock correction thus obtained with that by Mayer's method.

East Oakland, Cal., March 17, 1888. F. G. BLINN.

COME LEARN OF THE STARS.

Student, come hither, leave toiling by lamplight,
Night hath led forth in the heavenly fields
All of her star hosts emblazoned with splendor—
Silver their spears are, and silver their shields.

Yonder, bright Venus descends to the westward
  Leading the van of the glittering train,—
Bright but untwinkling goes Venus, the queen-star,
  Leading the hosts of the heavenly plain.

High in the zenith Orion is marching,
  Keeping his course like a veteran chief,
Wearing his sword like an emblem of office—
  Sword that hath never wrought anguish or grief.

Yonder the Pole-star the constant of heaven,
  Burneth his beacon for men on the sea;
Yonder goes Cygnus, the swan, flying southward,—
  Sign of the Cross and of Christ unto me.

Student, come hither, leave toiling by lamplight,
  Night hath led forth and her army is grand;
Almost methinks I can hear the bands playing,
  Hear the drums beating and words of command.

Why with this earth-life are we so enchanted?
  All that we win here must end in the sod;
Yonder the stars are, and yonder is Heaven,—
  Yonder is home and the angels and God.

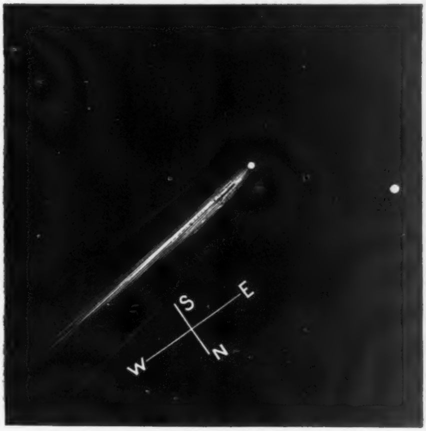
Fayette, Mo. T. BERRY SMITH.

EDITORIAL NOTES.

Historical Note Relative to the Name of the Planet Juewa (139). This planet was discovered October 10, 1874, at Peking, China, by Prof. J. C. Watson while in charge of the American Transit-of-Venus party at that station. At Watson's request the Chinese officials with whom he was in friendly relations, selected a name for the planet from which the present Juewa has been corrupted. There has recently come into my possession an envelope bearing the inscription in Watson's handwriting, "Card received from Prince Kung Nov. 26th, 1874, giving name to new planet discovered Oct. 10th, 1874, at Peking. Name reads *Jue' wha sing* or *Juewa-sing*, "The star of China's fortune." Literally, Jue, felicity or fortune, Wha, flowery or China, Sing, star." The envelope contains a strip of crimson paper with three Chinese characters written upon it which probably represent the name originally given to the planet. GEO. C. COMSTOCK.

Washburn Observatory, April 14, 1888.

The comet discovered by Mr. Sawerthal February 18, 1888, was observed at Carleton College, and two complete positions obtained, which are given below. On the morning of April 14 it was a beautiful object in the telescope, and could be picked up easily by the naked eye, if the observer knew where to look for it. Dr. H. C. Wilson made the accompanying drawing which well shows the appearance in the telescope. The nucleus was bright and sharp and pinkish white in color. The tail was about 2° long, faint in outline, but strongly bright along its axis or central line for its entire length. The star on the right side and near the margin is DM 15°4701, and was chosen for a comparison star, its magnitude being 9.0.



COMET *a* 1888 (APRIL 14).

Observations of Comet a 1888, made by H. C. Wilson with the 8¼ inch equatorial of Carleton College Observatory:

Date. 1888	Local Mean Time. h m s	Comet — * $\Delta\alpha$ m s	$\Delta\delta$ ′ ″	No. of Comparisons.	Star
April 11	16 38 38	—1 22.74	—10 41.5	6, 2	1
April 11	16 38 38	—2 28.71	— 8 56.8	6, 2	2
April 13	16 29 47	+3 46.44	— 6 12.3	6, 2	3
April 13	16 29 47	—0 18.21	— 5 46.9	6, 2	4
April 15	16 18 19	—0 14.58	— 0 54.4	6, 2	5
April 15	16 18 19	—2 08.58	+ 6 21.0	6, 2	6

No.	α app. h m s	l. f. p. α	δ app. ° ′ ″	l. f. p. δ
1	22 33 55.78	9.622n	+13 46 46.6	0.733
2	22 33 55.85	9.622n	+13 46 49.3	0.733
3	22 39 38.3	9.612n	+15 26.6	0.728
4	22 39 36.2	9.612n	+15 25.8	0.728
5	22 45 12.1	9.604n	+17 01.2	0.734
6	22 45 10.7	9.604n	+17 00.8	0.734

MEAN PLACES OF COMPARISON STARS.

Star.	α 1880.0 h m s	Red. to app. s	δ 1888.0 ° ′ ″	Red. to app. ″	*Authorities.
1	22 35 19.42	—0.89	+13 57 37.2	— 9.2	Greenwich 9 yr. Catalogue.
2	22 36 25.46	—0.90	+13 55 53.2	— 9.2	" " "
3	22 35 52.7	—0.84	+15 33.0	— 9.9	DM 15°4690 (8.5 mag.)
4	22 39 55.2	—0.84	+15 31.7	—10.0	DM 15°3701 (9.0 mag.)
5	22 45 27.5	—0.83	+17 02.3	—10.3	DM 16°4823 (9.3 mag.)
6	22 47 20.1	—0.84	+16 54.6	—10.3	DM 16°4830 (8.4 mag.)

The observations were made with a filar micrometer and have been corrected for refraction. The nucleus was about 8.5 mag., well defined and easy to bisect. The bisections for $\Delta\delta$ were made before and after the transits for $\Delta\alpha$, and the means of the times for $\Delta\alpha$ and $\Delta\delta$ were therefore nearly the same. When the difference between these means was greater than 10*s* the $\Delta\delta$'s were reduced to the times for the $\Delta\alpha$'s by applying the motion given in Dr. Krueger's ephemeris (A. N. 119.30).

The provisional longitude and latitude of Carleton College Observatory are:

Longitude 6*h* 12*m* 36.0*s* west from Greenwich.
Latitude $+44° 27' 42''$.

Orbit of Comet 1888 a. From observations of March 23rd, 30th and April 6th, I have computed the following orbit of comet 1888 *a*.

ELEMENTS.

$$T = 1888, \text{March } 16.99344 \text{ Gr. M. T.}$$
$$\pi\text{-}\Omega = 359°55'\ 6''$$
$$\Omega = 245\ 37\ 35$$
$$i = 42\ 18\ 14$$
$$\log q = 9.84516.$$

MIDDLE PLACE (C—O).

$$\Delta\lambda \cos\beta = +1''$$
$$\Delta\beta = -17''$$

The residuals in the middle place indicate that the orbit of the comet is probably elliptical, as already remarked by Dr. Becker and others. O. C. WENDELL.

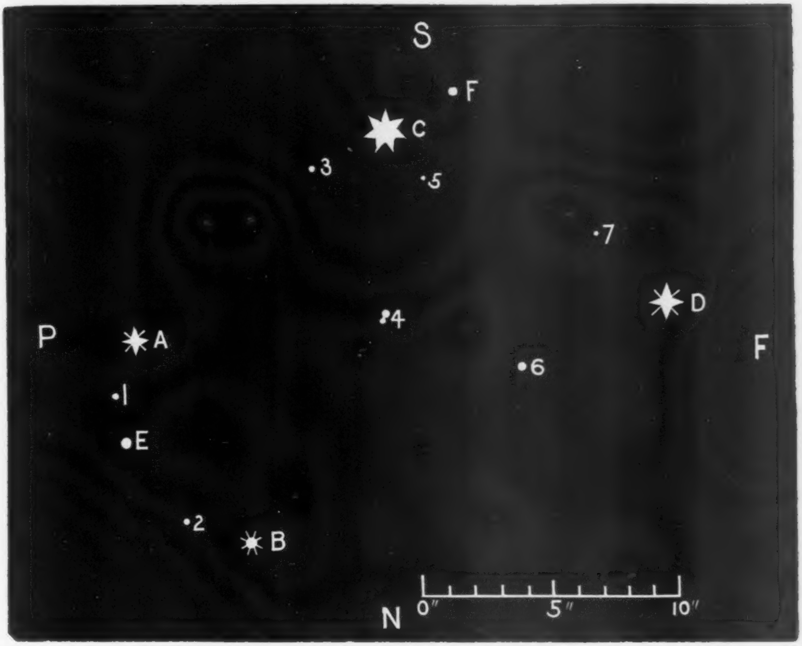
Harvard College Observatory, April 19th, 1889.

Comet a 1888. This comet was observed here this morning and presented a fine appearance in the 9-inch reflector. I made its approximate position 21*h* 40*m* in right ascension, and declination south 5°15′. It was just visible to the naked eye when well located. In the telescope the comet showed a bright nucleus, considerably elongated; the tail was very broad and about one degree in length. The sky was very clear this morning, the first we have had since the comet was far enough north to be visible in this latitude.

WILLIAM R. BROOKS.

Red House Observatory, March 25th, 1888.

θ Orionis. With regard to the nova in the trapezium of θ Orionis, mentioned on page 88 of the February number of THE MESSENGER as being discovered by Mr. Clark with the thirty-six-inch Lick equatorial, Mr Herbert Sadler of London kindly calls our attention to a letter of his which appeared in the *English Mechanic* for January 13, 1882 (letter 19610, p. 448, vol. xxxiv, No. 877.



TRAPEZIUM OF ORION.

Mr. Sadler thinks 6, Mr. Clark's nova in the above drawing (which is a copy of that published at the time above mentioned), was first seen by DeVico with a telescope of seven inches aperture in 1839. It has since been detected by Dr. Huggins with eight-inch aperture, and by Mr. Sadler with a twelve-inch. It is probably variable. Though the star in this drawing does not occupy the same relative place as that shown in Mr. Keeler's drawing in the February MESSENGER, it is so near it that probably Mr. Sadler is right.

Old and New Astronomy.—By kindness of the publishers, Messrs. Longmans, Green & Co., London and New York, we have a copy of the first part of Mr. Proctor's new book entitled *Old and New Astronomy*. This part contains 64 pages imperial octavo, in size of printed page, 5½ by 8½ inches, and consists of the Introduction and a little more than Chapter I of the complete book. The author starts with the place of Astronomy among the sciences, notices the vastness and impressiveness of its field of investigations, its power to elevate the mind and make great thoughts real, the practical uses of the science, and the place and honor rightly given to astronomers in the field of philosophical training. The first chapter treats of ancient and modern methods of observing the heavenly bodies. It is illustrated by upwards of forty good engravings, which make the historical part of the work attractive and easy of comprehension to the popular reader. We have not before seen this portion of the early history of astronomy so well presented as is given in this part. There is no question in our mind but that this, as a beginning is by far the best writing that Mr. Proctor has done in popular astronomy. If it shall be sustained as well as in its beginning, it will be a work of great usefulness.

As we have before said, it is to be published in monthly parts, all finally to be bound, making a book of 800 pages, at a price of twenty-six shillings if paid in advance.

Comet a 1888. The comet recently discovered near Cape Town, in South Africa, was observed on the morning of March 18th at 5:15 A. M. Washington mean time.

The head of the comet is quite bright; the tail about a degree and a half in length, well defined and presents rather a bushy appearance.

I picked the comet up with the comet-seeker at the Naval Observatory, which, through the kind permission of Captain Pythian, the superintendent, I have been using in comet hunting.

After finding it, Prof. Frisby secured only an approximate position, which was due to the absence from or near the field of a star by which a comparison of position could be made.

On the morning of March 19th, however, a comparison between the comet and the star in the field with it, was

made. After reducing the observation Prof. Frisby determined the position of the comet as in 21 hours, 19 minutes and 53 seconds in R. A.; 13° 21′ south declination. GEO. A. HILL.

Star Colors. In his interesting chapter on "Star Colors" in "Astronomy for Amateurs," W. S. Franks deprecates the use of any chromatic scale such as was proposed by Admiral Smyth in 1864 as a standard of comparison. It consisted of wafers showing four shades of each color, the deepest of which was called "1" and the palest "4," the objection to this being that the artificial light used at night would materially alter these hues and therefore render them unreliable as a standard of reference. He then points out that any system of reference should be based on the solar spectrum and indicates the place on the spectrum by the central wave number of the colors employed. While all this is of course true it is not very encouraging to amateurs who have only small telescopes and no spectroscopic attachments. The difficulty which many experience, without such aid, is to get a true idea of what the actual colors referred to are.

It is not easy to obtain any artificially prepared standards such as true red, blue or yellow. In order to test the matter, I recently inquired of some large manufacturers of paints, artists' materials, etc., if such existed, and they frankly admitted they knew of none.

I was shown many tints known by the name of one color, as for instance four samples varying from light yellow to full salmon, all known commercially, at least, as chrome yellow. It seems very desirable, therefore, to have artificially prepared standards of some kind based on the solar spectrum, not necessarily to be used at night, but to impress on the minds of those who would like to engage in the work of observing star colors what is meant by true red, blue, etc. When this is done we can no doubt more fully appreciate Mr. Frank's "chart of star colour nomenclature" shown on page 275 of the book referred to. JOHN H. EADIE.

Intersecting Rainbows. In No. 1 of the Publications of Morrison Observatory, a note was inserted on "Intersecting Rainbows" observed here in July 1884. As this phenomenon (on the assumed hypothesis), must always occur under a

certain rare combination of conditions, I expressed surprise, in the note, that in regions abounding in small lakes, no observation of it (so far as I know) had been made. I am glad that the publication has served to bring to light at least *one such observation*, made 83 years earlier. And though the subject matter belongs rather to Physics, than to astronomy, yet as astronomers, in every instance, have been connected with the observations, I hope that, in the interest of Science, I may ask for the publication of this note and of the accompaning letter from Herr H. Geelmuyden, assistant astronomer at the observatory at Christiania. It *may be* that there are *other observations*, and the publication may serve to bring them also to light, and even to compel writers on elementary physics to do full justice, at least, to the rainbow. The Norwegian astronomer, Christopher Hansteen, will be remembered, not only as the director and founder of the observatory at Christiania, but also as one of the most vigorous writers on magnetism, in the earlier years of this century.

[COPY OF LETTER.]

CHRISTIANIA OBSERVATORY, 1887, Dec. 20.

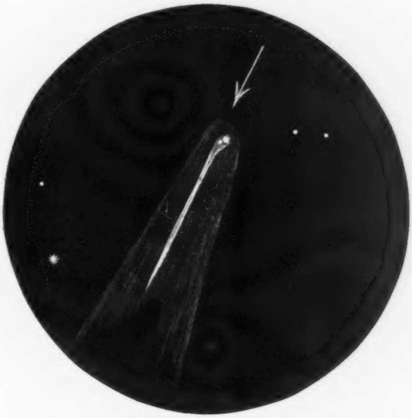
Sir: In the Publications of the Morrison Observatory, No I., I see a note on two intersecting rainbows, observed 1884, July 24, at your observatory. Perhaps it may interest you to know of a similar observation made many years ago by the late Professor Hansteen, and described by him in "Magazin for Natur-videnskaberne," Vol. I., Christiania, 1823. The description begins as follows:

"1821, Aug. 10, near the church of Slidre, in the valley of Valders (Norway), at 7 P. M., shortly before sunset, I saw two rainbows intersecting each other near the horizon, and near the east point, at an angle of 20 or 30 degrees, and then withdrawing further from each other at greater altitude. None of the bows were complete,—about the half on the right hand (towards the south) wanting. It was most remarkable that the colors in both followed in the same order as in the primary rainbow, and that both had equal intensity; so that neither I, nor my fellow travellers could decide which was the *genuine* one (*i. e.* that whose center was opposite to the sun), and which the mock one. The sun was already hidden from us by some high mountains towards the northwest."

The explanation given by Hansteen, is exactly similar to that suggested in your case. West and northwest of Slidre is the long and narrow Strandefjord (an extension of the river of the valley), enclosed between mountains,which generally protect it against the wind, and thus give it a smooth reflecting surface. Consequently the lake may have produced the reflection, giving the uppermost of the two rainbows. By calculation, Hansteen then proves the correctness of this hypothesis. I have the honor to be, sir, yours truly, H. GEELMUYDEN, *Assistant Astronomer.*

In conclusion I would express the wish that the scientific journals may take sufficient interest in the matter to elicit all the evidence available. C. W. PRICHETT.

Comet a 1888. On last Thursday morning, April 5th, while examining the head of the Sawerthal comet with the 8½-inch, micrometer eyepiece, power about 120 diameters, (equatorial of this Observatory), I saw in an instantthat the nucleus was composed of two distinct portions, as shown in the sketch herewith sent you. For several mornings it had appeared elongated in a direction corresponding to the line joining the two portions as seen divided on this date; and I have no doubt that I would have seen it *divided* on the earlier occasions had the atmosphere been as remarkably clear and steady as it was on the morning of the 5th, even at the low altitude of the comet.



Comet *a* 1888 (April 5th, 4:50 A. M.) Chabot Equatorial 8½-inch Aperture, Power 120.

By the aid of the micrometer, I estimated the separation equal to about 3″ (arc): that portion *n*.following was very decidedly the brighter. The duplicity was entirely unmistakable, even with illumination *slightly* turned on. I watched it long enough to be certain of the observation, before commencing micrometer measures for the comet's place; and on the succeeding morning recovered the field, identified the stars, and again convinced myself that one of the apparent nuclei was not a star. The bright star shown in the sketch is Arg. +7°: 4842; and Grant No. 5780.

I mentioned the observation to Prof. Holden, and at his suggestion, sent a telegram to Prof. Pickering at Cambridge. The two succeeding mornings' work did not verify the double nucleus to my complete satisfaction, but the air was far from "steady," either time. I await confirmation of this peculiarity with some interest. CHAS. B. HILL.

Chabot Observatory, Oakland, Cal., April 9th, 1888.

Solar Eclipse Aug. 19, 1887. In the account of the eclipse of August 19th, 1887, at pages 162 and 163 of THE SIDEREAL MESSENGER for April, 1888, the solar protuberances then visible are described and their relations discussed. It is stated that "at the first moment of totality four protuberances were visible on the eastern limit of the sun. The most southern had the greatest dimensions and could be seen even with the naked eye. By the progress of the moon three of the protuberances were covered but the most southerly one remained visible until the end of totality." Upon the western edge of the sun a group of protuberances was also observed, but they were "very low."

It is of interest to note the fact in connection with these observations that a brilliant group of faculæ was located precisely upon the sun's eastern edge at the point where the largest protuberance was seen. This group was in full view at Lyons, N. Y., at 5 o'clock P. M., on August 19th, and was followed by a small spot which was seen on the morning of August 20th. Allowing for difference of time the advance portion of this solar disturbance must have been exactly upon the sun's edge and foreshortened so as to be invisible at the very hour when Dr. Khandrikoff was making his observations. This condition of affairs justifies conclusions precisely the reverse of those which he states in regard to the relations between solar protuberances, spots and faculæ.

Lyons, N. Y., April 3rd, 1888. M. A. VEEDER.

Warner Comet Prize Decision. The claim of Mr. William R. Brooks to the discovery of the Olbers' comet, having been contested by Mr. Max Weir of Greenville, Ky., I was obliged to resort to arbitration, and the judges, Profs. E. E. Barnard, George Davidson and James G. Davidson of San Francisco, have awarded the prize to Mr. Brooks. The decision was unanimous as, in view of the evidence, I was quite sure it must be. Mr. Weir claims to have seen it three days previous in the northwest with his naked eye, whereas the Olbers-Brooks' comet has not at any time been visible in that direction, and is and has been only telescopic.

The claim of Mr. Brooks ought never to have been disputed. I saw the comet on the mornings of April 7th, 8th and 9th but failed on the 12th, though I had it in the field. It was too near the milky way to be seen again by any telescope, I think. LEWIS SWIFT.

Warner Observatory, Apr. 20th, 1888.

On the Adjustment of the Sextant. As I have at various times found it necessary to investigate the errors of a sextant, I was interested by the article of Professor Comstock in the April number of this journal.

So far as the adjustment of the index-glass is concerned I fully agree with the statements of Professor Comstock as to the needlessly crude character of the usual method; to me it has always seemed so very unsatisfactory that for some time past I have been giving a method to my students which it may not be out of place to give here.

The telescope-tube of the sextant—which we will call the *cylinder*—is to be set in a (nearly) vertical position on the (nearly) horizontal graduated arc, the eye-tube having first been removed in order that the cylinder may rest on an edge which is in a plane perpendicular to the axis of the cylinder. The index-arm is then to be turned until the cylinder and its image reflected from the index-glass appear to approach coincidence. If the mirror is *not* normal to the plane of the sextant the coincidence can not be secured as the corresponding outlines will not be parallel if we assume that the axis of the cylinder is normal to the plane of its base; to eliminate the error due to a slight inclination of the base, the cylinder should be revolved about its own axis until the position is found in which observed deviation from coincidence is the mean of the extreme deviations during a complete turn of the cylinder. If the coincidence, or parallelism of corresponding outlines is now complete, the index-glass is normal to the sextant.*

To test the accuracy of the adjustment of the index-gass by this method, a strip of plane glass six inches in length was placed under the cylinder and coincidence secured; a slip of paper 0.003 inches in thickness was then placed under the other end of the glass strip, thus causing the cylinder to tilt through an angle of about two minutes of arc; the deviation from coincidence was now readily detected.

To test whether the glass-surface (from which the reflections in these observations must take place) makes the same angle with the plane of the sextant that the silvered surface does, observe whether the two reflections of a white plumb-line three or four feet in length (best seen on a dark background, under an angle of incidence of about 60°) are parallel when the plane of the sextant is approximately horizontal. If the two surfaces are inclined to each other by an angle of only one minute of arc, the deviation from parallelism will

* If the cylinder is placed in a lathe and carefully centered, a slight trimming of the ends of the tube with the cutting tool will evidently form bases which are in planes perpendicular to the axis of the cylinder.

be apparent to the eye. By this method the inclination of the index-glass can be tested for all sextant-readings between 0° and 120°.

Ann Arbor, April 20th, 1888. M. SCHÆBERLE.

BOOK NOTICE.

A Treatise on Plane Surveying by Daniel Carhart, C. E., Professor of Civil Engineering in the Western University of Pennsylvania; Boston: Messrs. Ginn and Company, Publishers, 1888.

This new treatise covers quite fully the field of Plane Surveying. Large space is given to the illustration and description of instruments, including their adjustments and uses. Methods of work are exemplified by a variety of common problems, with solutions for special cases that often present themselves in practical work. It is evident that the writer is both a teacher and a practical surveyor, which give him the two-fold knowledge of the subject most needed in a text-book of this kind.

The plan of the book is as follows:

Chapter I. is devoted to chain surveying, and to give some idea how carefully and fully the subject is treated, we will notice the order of discussion. Section 1, instruments; Gunter's chain, two-pole chain, engineers' chain, tape measure, marking pins, straight poles. Section 2, chaining; how to chain, tallying, error in chaining, sloping ground, field exercises, ranging lines, over a hill, across a valley, through a wood, field exercises; to set a perpendicular to a line, through a point to run a perpendicular to a given line, obstacles to alignment, obstacles to measurement, measurement of heights, examples and field practice. In a similar way the four following sections under this topic treat recording field notes, mapping and plotting, areas, and offsets and tie-lines This chapter covers fifty pages of well selected matter with exercises and enough suitable illustrations. Chapter II. treats of compass and transit surveying to which 145 pages are devoted. A short chapter of twenty pages then follows on the variation of the compass. Chapter IV. is on laying out and dividing land. Chapter V. is devoted to plane table surveying; VI., to the survey of the public lands covering fifty pages; VII., to city surveying; VIII., to mine surveying followed by an appendix and a series of tables that are excellent in form and matter. We are a little surprised not to find in so good a book, some more reference to the elementary part of railroad surveying. In our field work for the last ten years, some of the finest exercises, for young classes, have been selected from this department of plane surveying. In the western part of the United States this branch of work leads all others at the present time.

This book contains 411 pages and 87 of tables and is every way a neat specimen of the printer's art.

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